Evaluation of the Production of Potassium Phosphate Fertilizer in Eastern Canada

Prepared for:
Department of Energy, Mines & Resources
Canmet, Mineral Sciences Laboratories

S.S.C. Contract No. 23440-7-9049/01-SQ

Kilborn Limited
March 1988

Evaluation of the Production of Potassium Phosphate Fertilizer in Eastern Canada

Prepared for:
Department of Energy, Mines & Resources
Canmet, Mineral Sciences Laboratories

S.S.C. Contract No. 23440-7-9049/01-SQ

This contract is funded under the

Canada-Nova Scotia Mineral Agreement

72 pp

Kilborn Limited
March 1988

MICROMEDIA

TABLE OF CONTENTS

SECTION	DESCRIPTION	PAGE NO.
1	SUMMARY	1- 1
2	INTRODUCTION	2- 1
3	TECHNICAL EVALUATION	3- 1
	3.1 SCREENING OF AVAILABLE TECHNOLOGIES	3- 1
	3.2 PROCESS EVALUATION	3- 5
	3.3 SOURCES OF SULPHUR	3-19
4	FINANCIAL EVALUATION	4- 1
	4.1 CAPITAL COST ESTIMATES	4- 1
	4.2 OPERATING COST ESTIMATES	4-11
	4.3 PRODUCT REVENUE ESTIMATES	4-18
	4.4 FINANCIAL EVALUATION	4-21
	4.5 PRODUCT MARKET POTENTIAL	4-23
5	SOCIO ECONOMIC AND ENVIRONMENTAL ANALYSIS	5- 1
	5.1 SOCIO ECONOMIC PROFILE	5- 1
	5.2 ENVIRONMENTAL OVERVIEW	5- 3
6	CONCLUSIONS AND RECOMMENDATIONS	6- 1

Kilborn has followed standard procedures in preparing the evaluation in the Report but the Report is based in part on details, information and assumptions provided by others and Kilborn, therefore, cannot guarantee the correctness of the Report; but to the extend of its investigation and within the scope of the work delegated to it, Kilborn believes the Report is substantially correct.

1.0 SUMMARY

Potassium phosphates have been long recognized as a potentially attractive fertilizer product because of their high nutrient content, their chloride-free advantage over commodity potash fertilizers, their slow release characteristics and excellent agronomic properties in general. However, production technologies have not existed for their production at prices competitive with commodity fertilizers. Limited quantities have been produced for chemical applications by the direct conversion of phosphoric acid and potassium hydroxide; however, their cost has been in the range of $1000-1200 per tonne, several times that of commodity fertilizers.

This study examined a number of technologies to determine their potential for the production of potassium phosphate fertilizers in Atlantic Canada from New Brunswick potash, imported phosphate rock and a local source of sulphur. The processes were evaluated on the basis of their ability to meet the study objectives, commercial readiness or stage of development, commitment of the participating parties to the continued development and commercialization of their technology and the availability of sufficient technical and cost data to permit a valid evaluation to be made. Three processes were selected for further evaluation, including:

- The PCS/PECO High Temperature Melt Process
- The PCS/PECO Ion Exchange Process
- The Pennzoil Process (two versions)

Two of the three processes were found to be of particular interest, the High Temperature Melt Process being developed by Potash Corporation of Saskatchevan (PCS) and Phosphate Engineering and Construction Co. (PECO) and the Potassium Phosphate Process being promoted by Pennzoil.

In the PCS/PECO Process, which is the subject of current patent applications, potash is reacted with wet process phosphoric acid at elevated temperature to produce an impure potassium phosphate melt and by-product hydrogen chloride which is recovered as aqueous hydrochloric acid. High purity monopotassium phosphate is recovered from the melt using conventional technology. Phosphoric acid for use in the main process is produced from phosphate rock and sulphuric acid using conventional wet process technology. PCS and PECO have demonstrated the high temperature melt process in laboratory scale equipment and are currently constructing a continuous pilot plant in Saskatoon to confirm the concept in larger scale equipment and to establish design criteria for commercial scale facilities. Commissioning of the pilot plant is expected in the second quarter of 1988.

In the Pennzoil Process, potash is reacted with sulphuric acid at 110-125°C to produce potassium bisulphate and by-product hydrochloric acid, as in the PCS/PECO Process. The potassium bisulphate and additional sulphuric acid are than reacted with phosphate rock to produce a potassium phosphate/phosphoric acid double salt. The double salt is contacted with methanol to effect a separation and precipitate the potassium phosphate as monopotassium phosphate, which is recovered by conventional filtration, washing and drying operations. Pennzoil has demonstrated production steps through to the formation of the double salt in semi-commercial facilities but has only completed laboratory investigations on the methanolic precipitation stage. Pennzoil has no plans to further develop its technology, although PECO recently entered into an agreement with Pennzoil to explore commercialization prospects for the technology.

Overall material balances, capital cost, operating cost and product revenue estimates were prepared for a facility with a capacity to produce 100 000 tonnes per year of monopotassium phosphate fertilizer and associated quantities of co-produced fertilizers, feed grade dicalcium phosphate and by-product hydrochloric acid.

A financial summary is presented in Table 1.1 for the processes evaluated, including capital cost, production cost and product revenue estimates for the 100 000 tonne per year potassium phosphate facility. As indicated in the Tables, the PCS/PECO High Temperature Melt Process has the lovest estimated capital cost at $65.0 Million and the best gross margin (product revenue minus direct operating cost) at $2.0 Million per year. This is followed by the Pennzoil Processes at higher capital cost and zero or slightly positive gross margins and finally the PCS/PECO Ion Exchange Process with the highest estimated capital cost of $99.9 Million and a production cost which exceed estimated product revenue by $9.4 Million per year.

Gross margin and therefore project financial potential can be increased for either the PCS/PECO High Temperature Melt Process or the Pennzoil Processes if a higher price can be realized for the monopotassium phosphate fertilizer product to reflect its advantages over competitive fertilizers, high nutrient content in excess of 80 percent and chloride-free (lov salt index) properties. Additionally, project attractiveness is improved if sulphuric acid is priced lover to reflect a possible surplus of smelter acid as a result of stricter SO_2 emission regulations. By increasing monopotassium phosphate prices to $350 per tonne from $300 per tonne to reflect its superior qualities (priced competitively with potassium sulphate, the present source of chloride-free K fertilizer) and by decreasing sulphuric acid price from $60 to $40 per tonne to reflect a surplus of smelter acid, estimated gross margin for the PCS/PECO High Temperature Melt Process is increased to $9.9 Million per year, resulting in an indicated payback period of 6.6 years on the initial investment.

Construction and operation of a potassium phosphate fertilizer plant in the Cape Breton area of Nova Scotia would have a number of direct and indirect benefits on the region. Job opportunities would be created in the construction and operation of the plant and in service industries to support the plant and its employees, personal income would increase,

unemployment would be reduced and federal and provincial taxes would increase. An estimated 160 direct and indirect jobs would be created for operation of the plant as well as 300-500 man years of direct employment during construction of the plant.

Emissions from a potassium phosphate fertilizer complex would be similar to those experienced from a conventional vet process acid plant, including fluorides, particulates, sulphuric acid, sulphur dioxide and potentially radionuclides plus hydrogen chloride from the potash processing units. These potential emissions are well understood and the technology exists for their control to meet applicable effluent guidelines. Handling of waste phosphogypsum, often considered an aesthetic problem, is well established and is usually not a problem if placed on a suitable earthen foundation and if water runoff is controlled to prevent the possible contamination of surface or groundvater. Storage pond facilities for the safe handling of waste phosphogypsum from the proposed plant are included in the complex evaluated in this study.

Based on findings of this study, it is recommended that a detailed feasibility study be undertaken to more fully evaluate the technical and financial viability of the PCS/PECO High Temperature Melt Process and to better assess the market opportunity and probable price for potassium phosphate fertilizers to take advantage of their chloride-free, low salt index properties and high nutrient value. In addition to its apparent technical and financial potential, PCS and PECO are both committed to its continued development and commercialization. Further PCS has indicated a villingness to cooperate in a more detailed evaluation of the process as it relates to Atlantic Canada.

The detailed feasibility study, to be recommissioned once PCS and PECO have completed their pilot ploant development scheduled for 1988, should evaluate technical, marketing, financial, socio economic and environmental impact aspects of a potential potassium phosphate fertilizer project.

The technical evaluation would develop a Process Flowsheet and process equipment requirements for a given capacity plant, probably 100 000 tonnes per year of monopotassium phosphate product, and investigate possible product flexibility to be built into the plant.

The marketing evaluation would assess the agronomic value of potassium phosphate fertilizers and their probable competitive position relative to potash as the source of K and triple superphosphates or ammonium phosphates as the source of P and project the probable price per tonne FOB Port relative to the competitive fertilizers. Additionally, the probable markets and price for by-product hydrochloric acid should be assessed as without the sale of this important by-product, financial attractiveness of the project is unlikely.

The financial evaluation would define the estimated project capital cost, operating cost, product revenue and financial potential via a preliminary financial and sensitivity analysis which assess the effect of selected financial and cost parameters on the indicated project rate of return.

A socio economic reviev would assess the direct and indirect benefits and impacts of such a plant on the local community and region, including employment opportunities, impact on the existing infrastructure and general benefits to industry in Atlantic Canada.

The environmental impact assessment should identify potential emissions from the plant, the technologies needed for their control to meet all applicable environmental guidelines and the potential impact on the surrounding environment.

TABLE 1.1
FINANCIAL SUMMARY TABLE

		PCS/PECO HIGH TEMP BASE CASE	PCS/PECO ION EXCH	PENNZOIL RECYCLE	PENNZOIL ONCE THRU
Capital Cost	$M	65.0	99.9	69.1	75.5
Production Cost	$M/YR	34.5	55.0	37.3	69.8
Product Revenue	$M/YR	36.5	45.6	37.3	71.2
Gross Margin (Revenue - Prod. Cost)		2.0	(9.4)	0	1.4
PRODUCTION COSTS $M/YR					
Raw Material Cost					
Potash (KCL)		5.4	7.5	5.2	5.8
Phosphate Rock (68% BPL)		9.6	13.5	9.6	23.2
Sulphuric Acid (98%)		9.8	13.9	8.6	20.8
Lime		---	2.1	---	---
Ammonia		---	0.7	---	3.7
Utilities		1.9	5.3	5.7	7.1
Operating & Misc.		7.7	12.1	8.3	9.3
Total Operating Cost		34.5	55.0	37.3	69.8
PRODUCT REVENUE $M/YR					
Monopotassium Phosphate (MKP)		30.0	30.0	30.0	30.0
HCL		6.5	---	7.3	7.3
Monoammonium Phosphate (MAP)		---	6.2*	---	33.9
Dicalcium Phosphate		---	9.4	---	---
Total Revenue		36.5	45.6	37.3	71.2

* Ammoniated Metallic Phosphates

All cost 1987 basis

1.0 RESUME

Le phosphate de potassium a été longtemps reconnu comme un engrais ayant beacoup de potentiel principalement dû à sa haute teneur en nutrient, l'absence de produit chloré par rapport aux autres engrais de potassium, leur lente émission ainsi que leur excellente propriété agronomique. Par contre les techniques de production compétitives face aux engrais utilisés n'existaient pas. Des quantités limitées étaient produites pour utilisation chimique à partir de la réaction de l'acide phosphorique avec l'hydroxyde de potassium; les coûts de conversion se situaient dans l'ordre de $1000-1200 par tonne, plusieurs fois le coût de production des engrais utilisés.

Cette étude évalue un certain numbre de procédé afin de déterminer leur potentiel de production d'engrais à base de phosphate de potassium localisé dans les Maritimes en utilisant la potasse du Nouveau-Brunswick, de la roche de phosphate importé ainsi que' l'utilisation du soufre local. Les procédés ont été évalués pour rencontrer les sujets suivants: les objectifs de l'étude, la disponibilité commerciale ou leur stage de developement, l'intérêt des participants dans la poursuite de recherche, sur le développement et la commercialisation de leur technologie ainsi que la disponibilité de données techniques et de coûts suffisants permettant une évaluation valable. Trois procédés ont été choisi pour une évaluation plus élabore tel que.

- Le PCS/PECO le procédé de fusion a haute température.
- Le PCS/PECO le procédé d'échangeur d'ions.
- Le procédé Pennzoil (deux versions).

Deux procédés parmi les trois procédés mentionnés se sont révélés intéressant. Soit le procédé de fusion à haute température développé par Potash Corporation of Saskatchevan (PCS) et Phosphate Engineering and Construction Co. (PECO) ainsi que le procédé de phosphate de potassium développé par Pennzoil.

Dans le procédé PCS/PECO breveté, la potasse réagit avec de l'acide phosphorique à haute température afin de produire une fusion de phosphate de potassium impure en plus de produire de l'acide chlohydrique. Le phosphate de potassium de haute purité peut être récupéré par des procédés conventionnels. L'acide phosphorique utilisé provient de la réaction de la roche de phosphate avec l'acide sulfurique, suivant le procédé conventionnel. Les compagnies PCS/PECO ont experimenté la fusion du phosphate de potassium avec de l'équipement de laboratoire; présentement ils construisent une usine pilote à Saskatoon afin de montrer la viabilité et les critères de conception à l'échelle commercial; le démarrage de l'usine est prévu pour le deuxième quart de 1988.

Dans le procédé de Pennzoil, la potasse réagit avec de l'acide sulfurique à une température de 110-125°C produisant un bisulfate de potassium ainsi que de l'acide chlrohydrique tout comme dans le procédé de PCS/PECO.

Le bisulfate de potassium avec une quantité additionnel d'acide sulfurique réagit avec de la roche de phosphate produisant un sel double de phosphate de potassium/acide phosphorique. Ce sel est mis en contact avec du méthanol qui permet la séparation et la précipitation du phosphate de potassium sous forme de mono phosphate de potassium qui est récupéré selon les méthodes conventionnelles de filtration, lavage et séchage.

Le méthanol est séparé de l'acide phosphorique puis recyclé.

La co-production d'acide phosphorique peut être recyclé afin de produire du phostphate de potassium additionnel ou le traiter pour produire un diammonium de phosphate ou de l'acide phosphorique de grade commercial. Pennzoil a démontré semi-commerciallement la formation du sel double, par contre la précipitation avec le méthanol n'a pas dépassé le stage de laboratoire. Pennzoil n'envisage pas presentement d'accentuer le dévelopement de sa technologie même si PECO a récemment signé un accord avec Pennzoil pour la possibilité de commerialiser le procédé de PECO.

Basé sur les donnés obtenues de l'étude, il est recommandé q'une étude détaillé de faisabilité soit exécuté afin de démontrer la viabilité technique et financière du procédé de fusion à haute température développer par les compagnies PCS/PECO; et ainsi mieux estimer le marché et le prix du phosphate de potassium en tenant compte des avantages qu'il représente c'est-a-dire libre de composé chloré, un faible indice de sel et sa haute teneur en nutrient. En plus du potentiel technique et financier, PCS et PECO sont dédiés à continuer le dévelopement technique et commercial de leur procédé. De plus PCS a démontré un désir de participer a une évaluation détaillée du procédé dans son application dans les régions d'Atlantique du Canada. L'étude détaillée de faisabilité devrait être initie apresque PCS/PECO est complété leur cédule de démarrage de leur usine pilote, cette étude devrait couvrir l'évaluation technique, commercial, financière, socio-economique et l'impact environnementale d'un projet de production d'engrais à base de phosphate de potassium.

L'évaluation technique produira un schéma d'écoulement du procédé ainsi que l'équipement requis pour une capacite donné tel que une production de 100 000 tonnes par année de phosphate de potassium et estimé la flexibilite de production inhérente à l'usine.

L'évaluation du marché évaluera la valeur agronomique du phosphate de potassium et sa position compétitive face à la potasse source de potassium et le superphosphatetriple ou le diammonium de phosphate source de phosphore, permettant la projection propable du coût par tonne FOB en relation avec les autres engrais. De plus le marché et le prix du sous-produit , soit L'acide chlorhydrique, devrait être évalué car sans les ventes de ce sous-produit le projet devient financièrement moins attrayant.

L'évaluation financière définira le coût d'investissesment du projet, le coût d'opération, les revenues provenant de la vente des produits ainsi que le potential financier obtenu par une analyse financière préliminaire qui évalura les effets du choix de financement et des paramètres coûts sur le taux de revenue sur investissement.

Une étude socio-économique évaluera les bénéfices directs et indirects ainsi que l'impact d'une tel usine sur la municipalité locale et régionale incluant la création d'emplois, l'impact sur les infrastructures existantes et les bénéfices généraux pour l'industrie des régions de L'Antlantique Canadienne.

L'impact sur l'environnement évaluera les émissions de contaminant possible, les technologies requises pour leur contrôle afin de rencontrer les normes gouvernementals et leur impact sur l'environnement immédiat.

Un bilan matériel, les coût d'investisseement, coût d'operation et revenu de la vente des produits ont été évalué pour une usine de 100 000 tonnes par annee de phosphate de potassium incluant la production de co-produits, et l'alimentation en roche de phosphate.

Un résumé financier est présenté à la table 1.1 pour les procédés évalués dan cette étude, pour une production de 100 000 tonnes par année de phosphate de potassium. Tel qu'indiqué dans les tables, le procédé de fusion à haute temperature développé par PCS/PECO possède le plus faible coût d'investissement soit 65 millions et le meilleure retour sur investissement sort 2 millions par annee. Le procédé de Pennzoil suit avec un coût d'investissement plus élevé et un retour presque nul; finalement le procédé d'echange d'ions de PCS/PECO présente un coût d'investissement de 99 millions et un coût de production excédent de 9.9 millions les revenues de la vente des produits.

Les revenues brut peuvent être amélioré pour les procédés de fusion à haute température de PCS/PECO et de même pour le procédé de Pennzoil si un prix plus eleve pouvait être réaliser en marchandant les avantages du phosphate de potassium sur les engrais réguliers, tel qui un excédent de 80% de nutrient et l'absence de composé chloré (faible indice de sel).

De plus l'attrait du projet augmente si le prix de l'acide sulfurique est réduit pour réfleter l'excédent de production provenant des "smelter", dû au norme plus stricte face a l'émission d'anhydride sulfureux. En augmentant le prix du phosphate de potassium de 300 a 380 dollars par tonne, justifié par sa qualité supérieure et un prix compétitif face au sulfate de potassium la source principale d'engrais libre de composé chloré.

De plus en diminuiant le coût de l'acide sulfurique de 60 a 40 dollars la tonne, justifié par le surplus d'acide provenent des smelter, les revenus brut pour le procédé PCS/PECO fusion à haute température sont augmentés à 9.9 millions par année, produisant un retour sur investissement de 6.6 années.

La construction et l'opération de l'usine de phosphate de potassium dans la région du Cap Breton en Nouvelle Ecosse pourrait rapporter des bénéfices directs et indirects pour la région. Soit des opportunités d'emplois créés pars la construction et l'opération de l'usine ainsi que dans les industries de service de support pour l'usine et les employées. Les revenus des personnes augmenteraient, le chômage diminurait tandis que les impôts Provincial et Fédéral augmenteraient.

Une création de 160 emplois directs et indirects sont estimés en plus de l'utlisation de 300 à 500 hommes-années pour la construction de l'usine.

L'émission de contaminent d'une usine de phosphate de potassium serait similaire aux émission d'une usine de production d'acide phosphorique tel que fluorure, poussières, acide sulfurique, d'anhydride sulfureux et possibblement "radionuclides" et de l'acide chlohydrique. Les émissions possible sont bien connu ainsi que les techniques de contrôle pour rencontrer les normes requises. La manipulation de résidu de gypse en générale ne présente aucum problème si on dispose d'un terrain stable et que l'eaux de ruissellement est contrôlé afin de prévenir toute contamination des eaux de surface. Des bassins de sédimentation sont prévus pour l'entreposage du gypse provenant de l'usine considéré dans cette étude.

TABLEAU 1.1

RESUME FINANCIER

	PCS/PECO BASE CASE HAUTE TEMP.	PCS/PECO ECH. D'ION	PENNZOIL RECYCLE	PENNZOIL SANS RECIRCULATION
Coût d'investissement $M	65.0Base	99.9	69.1	75.5
Coût Production $M/YR	34.5	55.0	37.3	69.8
Revenus des Produits $M/YR	36.5	45.6	37.3	71.2
Profit	2.0	(9.4)	0	1.4
COÛT PRODUCTION $M/ANNÉE				
Coût Matière Première				
Potasse	5.4	7.5	5.2	5.8
Roche Phosphate (68% BPL)	9.6	13.5	9.6	23.2
Acide Sulfurique (98%)	9.8	13.9	8.6	20.8
Chaux	---	2.1	---	---
Ammoniaque	---	0.7	---	3.7
Utilités	1.9	5.3	5.7	7.1
Coût d'pération	7.7	12.1	8.3	9.3
Coût Total d'opération	34.5	55.0	37.3	69.8
REVENUS DES PRODUITS				
Monopotassium De Phosphate (MKP)	30.0	30.0	30.0	30.0
HCL	6.5	---	7.3	7.3
Monoammonium De Phosphate (MAP)	---	6.2*	---	33.9
Dicalcium De Phosphate	---	9.4	---	---
Revenu Total	36.5	45.6	37.3	71.2

* Phosphate De'ammonium Métallisé

Coût Basé 1987

2.0 INTRODUCTION

North American fertilizer production is highly competitive and supply is currently abundant. In Canada, the production of solid fertilizers includes potash as a source of Potassium (K), urea as a source of Nitrogen (N), triple superphosphate as a source of Phosphate (P) and monoammonium phosphate as a source of N and P. Canadian potash is exported worldvide as Canadian producers in Saskatchevan and Nev Brunswick are major contributors to the world supply of potash. Current production rate is in the order of 12 million tonnes per year (7 million tonnes of K_2O equivalent).

Potassium-based fertilizers can take other forms including sulphate, nitrate and phosphate. Potassium phosphates, although not currently used as commodity fertilizers due to the high prices, are of considerable interest because of their high nutrient value and their chloride-free nature. Shipping and storage costs for high nutrient value potassium phosphates, 80-85 percent for mono-potassium phosphate and 90-100 percent for potassium polyphosphates, vould be significantly lover than for their lower nutrient value competitive products. In addition, being a chloride-free fertilizer, potassium phosphates could replace potash fertilizer in areas where chloride buildup in the soil or plant sensitivity to chlorides is a concern. Agronomic studies have confirmed that potassium phosphates are high quality, slow release fertilizers.

Technology is currently being developed for the economic production of potassium phosphate fertilizers from potash, sulphuric acid and phosphate rock. A possibility appears to exist for the economic production of potassium phosphate fertilizers close to a Maritime port as potash is available from Nev Brunswick, phosphate rock is readily and economically available from North Carolina or Florida, sulphuric acid can be purchased or manufactured locally and products can be exported by ocean freight.

It was in this context that Kilborn Limited was selected to conduct a prefeasibility study on the potential of producing 100 000 tonnes per year of potassium phosphate in Cape Breton, Nova Scotia.

This prefeasibility study encompassed a number of tasks, including:

- An assessment of the available technologies for the production of potassium phosphate fertilizers from potash, phosphate rock and sulphuric acid (or other source of sulphur) and selection of the most appropriate technology for the region.

- An evaluation of the sources of sulphur available in the Atlantic region for the production of sulphuric acid and an initial indication of the resultant sulphuric acid costs.

- An estimation of capital and operating costs for potassium phosphate fertilizer plants using the leading production technologies and an initial assessment of their financial potential.

- Preliminary review of the potential market and probable realization price for potassium phosphate fertilizers.

- Preparation of a brief socio-economic profile for a potassium phosphate fertilizer plant.

- Discussion of the environmental impact of such a plant on the neighbouring communities and region.

- Preparation of the terms of reference for a more detailed feasibility study.

3.0 TECHNICAL EVALUATION

3.1 SCREENING OF AVAILABLE TECHNOLOGIES

A number of technologies were identified as being potentially available for the production of monopotassium phosphate fertilizer (MKP) in Eastern Canada from New Brunsvick potash, imported phosphate rock and a local source of sulphur (elemental sulphur, sulphuric acid or sulphur dioxide):

- Two PCS/PECO Processes
- Pennzoil Process
- Pennzoil/Prodeco Process
- Pritchard-Fraxon Process
- IMI Process

Each process was evaluated on the basis of its ability to meet the study objectives (production of MKP), commercial readiness or the stage of development, commitment of participating parties to the continued development and commercialization of the technology and the availability of sufficient technical and cost data to permit a valid evaluation to be made.

PCS/PECO Ion Exchange Process

The Potash Corporation of Saskatchevan (PCS) and Phosphate Engineering and Construction Co. (PECO) are currently developing an Ion Exchange Process for the conversion of potash and vet process phosphoric acid to MKP using a monoammonium phosphate (MAP) intermediate. Novel processing steps in the technology have been successfully demonstrated in pilot scale facilities, whereas other steps have been commercially proven in similar process applications. Technical and cost information provided by PCS to Kilborn in a confidential report were used as the basis for process screening, technical and cost evaluation activities.

PCS/PECO High Temperature Melt Process

In the PCS/PECO High Temperature Melt Process, for which a patent application has been made, potash and wet process phosphoric acid are reacted at elevated temperature to evolve hydrogen chloride gas and yield an impure MKP melt. Product grade MKP is recovered by subsequent treatment of the melt and removal of the undesirable impurities. The concept has been evaluated in laboratory scale equipment and a pilot scale demonstration circuit is currently under construction in Saskatoon, with commissioning scheduled for the second quarter of 1988. Technical and cost information provided by PCS to Kilborn in a confidential report were used as the basis for this study.

Pennzoil Process

The Pennzoil Process involves the production of potassium bisulphate from potash and sulphuric acid, followed by the production of a potassium phosphate/phosphoric acid double salt from the potassium bisulphate, additional sulphuric acid and phosphate rock and recovery of the MKP via methanolic precipitation. The co-produced phosphoric acid can either be recycled for the production of additional MKP or recovered for sale, either directly as phosphoric acid or indirectly as MAP by ammoniation/granulation. All process steps up to production of the double salt have been successfully demonstrated in small commercial scale facilities, whereas only limited development of the methanolic precipitation step has been completed. Pennzoil has no plans for further development of the technology; however, PECO has recently entered into an agreement with Pennzoil to develop commercialization prospects for the technology.

Pennzoil/Prodeco Process

The Pennzoil/Prodeco Process is similar to the Pennzoil Process except that monocalcium phosphate, which is produced from phosphate rock via acidulation with phosphoric acid, is used in the process and the MKP is recovered via controlled concentration and crystallization. As

conversion of monocalcium phosphate and potassium bisulphate to MKP is not expected to be substantially different than the similar conversion with phosphate rock, this process step can be considered to be commercially proven. However, very little information is available on the controlled concentration/evaporation step particularly in the presence of impurities that are known to promote the precipitation of double salts rather than MKP. It is for this reason that monocalcium phosphate rather than phosphate rock is used in the process.

Pritchard-Fraxon Process

In the Pritchard-Fraxon Process, potassium bisulphite is produced from potash and sulphur dioxide via an ion exchange/regeneration procedure using acetone sulphonic acid/potassium acetone sulphonate intermediates, followed by conversion of the unstable potassium bisulphite to potassium sulphite and sulphur dioxide for recycle. The potassium sulphite, or potentially the potassium bisulphite, is then converted to potassium phosphate via reaction with phosphoric acid or monocalcium phosphate which have been produced from phosphate rock. The first stage of the process, production of the bisulphite, has been demonstrated in large scale pilot equipment with sodium salts. By contrast, only basic chemical reactions have been explored for the final stage production of the potassium phosphate and no significant laboratory work has been performed or is planned.

IMI Process

The Israeli Mining Industries (IMI) Process involves the direct conversion of potash and phosphoric acid to a potassium phosphate/phosphoric acid double salt in the presence of an organic heat transfer medium, followed by extraction of the phosphoric acid and precipitation of the potassium phosphate. The process has been demonstrated in pilot scale facilities. However, very limited technical and cost information is available and no further development is anticipated as IMI is concentrating on commercialization of its potassium sulphate and potassium nitrate technologies.

Process Screening

Based on an initial screening of the available potassium phosphate fertilizer technologies, their stage of development and commitment of the participating companies to continue their development, the Pennzoil/Prodeco, Pritchard-Fraxon and IMI Processes were dropped from further evaluation and a more detailed technical and financial evaluation of the PCS/PECO and Pennzoil Processes was performed to select the process that best meets the requirements of an Eastern Canadian potassium phosphate production facility. Details of this evaluation are presented in the following sections of this report.

The Pennzoil/Prodeco Process was dropped from further evaluation as the final controlled concentration/crystallization step is only in an early stage of development, because of its envisaged complexity and as it does not appear to offer any technical or cost advantages over the Pennzoil Process. The Pritchard-Fraxon Process was excluded as it is in a very preliminary stage of development and no significant laboratory data are available to confirm the feasibility of the final process steps. By contrast, the IMI Process was dropped as IMI is no longer committed to its development and because of its complexity resulting from the use of two separate organic solvents to facilitate the main process steps.

3.2 PROCESS EVALUATION

The three process selected for further evaluation during the initial technology screening activity were subjected to a more detailed analysis, including a thorough review of available information, preparation of Block Flow Diagrams and overall material balances, definition of feedstock and utility requirements and a comparison of their advantages and disadvantages. All processes were compared on the basis of the production of 100 000 tonnes per year of monopotassium phosphate (MKP) fertilizer plus the associated quantities of by-products.

The three processes selected for further evaluation were:

- PCS/PECO High Temperature Melt Process
- PCS/PECO Ion Exchange Process
- Pennzoil Process

Two versions of the Pennzoil Process were evaluated, the Recycle Mode in which co-produced phosphoric acid is recycled for the production of additional MKP and the Once Through Mode in which the co-produced phosphoric acid is ammoniated and granulated to produce monoammonium phosphate (MAP) or potentially diammonium phosphate (DAP).

Confidential technical and cost information provided to Kilborn by PCS was used as the basis for this technical evaluation; as such, the following process details are of a general nature. In-house information was used as the basis for the technical evaluation of the Pennzoil Process; this information has been assembled over the past 8 years as Kilborn has followed development of the technology and has assessed it previously for Environment Canada (1981), the Province of Nova Scotia (1982), the Province of Saskatchewan (1983) and in an internally funded study for the Province of Ontario (1985).

PCS/PECO High Temperature Melt Process

An overall Block Flow Diagram for the PCS/PECO High Temperature Melt Process is presented in Figure 3.1. In the process, which is the subject of patent applications, potash is mixed directly with wet process phosphoric acid from a conventional phosphoric acid production plant in a high temperature reaction unit. Hydrogen chloride gas is evolved, resulting in the formation of a potassium phosphate melt according to the overall reaction.

$$KCl + H_3PO_4 \longrightarrow KH_2PO_4 + HCl$$

The potassium phosphate melt, which contains unreacted potash, phosphoric acid and impurities contained in the feed materials, is subjected to further treatment to extract the MKP and convert the impurities into a form which simplifies their removal. The impurities, are removed and discarded, or subjected to further processing to produce a high nutrient value, slow release fertilizer.

Storage tests of the MKP solid product, held in open containers indoors for over 24 months, show no significant hydroscopicity or caking tendency.

Hydrogen chloride evolved in the high temperature reaction step is recovered as aqueous hydrochloric acid (20° or 22° Be), or potentially as anhydrous HCl, and pumped to storage for sale as an important by-product.

Phosphoric acid used in the process is produced from imported phosphate rock and local sulphuric acid via conventional phosphate rock acidulation technology. The Nissan Hemihydrate Process was selected for use in the study as being representative of the technology. In the process, phosphate rock is acidulated with sulphuric acid to produce phosphoric acid and calcium sulphate in the hemihydrate form. Filtration of the acidulation slurry yields product acid (50% P_2O_5)

directly. The recovered hemihydrate is redissolved, hydrated to dihydrate or gypsum and refiltered to remove the gypsum. Incremental P_2O_5, recovered during the hydration step, is recycled and the gypsum product, although potentially a saleable by-product, is discarded.

Overall feedstock requirements for a 100 000 tonne per year MKP production rate are given in Table 3.1.

The high temperature reaction step has been successfully demonstrated in laboratory scale equipment by PCS and PECO. All other processing steps are considered to be commercially proven in similar applications. Pilot scale demonstration of the process concept is currently under construction to confirm the high temperature reactor operation in larger scale equipment, to evaluate the possible build-up of contaminants in recycle, to establish overall process material and energy efficiencies and to develop information for the design of commercial scale facilities. This pilot circuit, designed to produce 100 lbs per day of MKP, on a continuous basis, is expected to be commissioned in the second quarter of 1988.

PCS/PECO Ion Exchange Process

An overall Block Flow Diagram for the PCS/PECO Ion Exchange Process is presented in Figure 3.2. In this process, which is the subject of two patents, phosphoric acid from a conventional phosphate rock acidulation plant (a Nissan Hemihydrate Process as discussed earlier) is ammoniated in an agitated reactor to produce monoammonium phosphate (MAP).

Conditions in the reactor are controlled to precipitate metallic impurities in the phosphoric acid as ammoniated metallic phosphates. The MAP solution is diluted with recycle solution and is used as a feedstock for the ion exchange operation. The ammoniated metallic phosphate precipitate is recovered by filtration, dried and dispatched to further processing and storage for sale as a dry slow-release fertilizer product.

Monopotassium phosphate (MKP) is produced from the MAP solution and a solution of potash KCl via ion exchange. The resin is loaded with potassium ions by passing the solution of KCl through the resin bed. The MAP solution is then passed through the loaded resin bed resulting in an exchange of potassium ions for ammonium ions and the resultant production of MKP. The ammonium ions are stripped from the resin during the subsequent regeneration step with KCl, resulting in the production of ammonium chloride. The overall reactions are as follows with X as the active resin site:

$$NH_4H_2PO_4 \text{ (MAP)} + KX \longrightarrow KH_2PO_4 \text{ (MKP)} + NH_4X$$

$$NH_4X + KCl \text{ (Potash)} \longrightarrow KX + NH_4Cl$$

MKP solution from the ion exchange unit is contacted with incoming potash (KCl) in a multiple stage crystallizer, precipitating MKP by the common ion effect. The product MKP is recovered by centrifugation, dried in a conventional dryer and transferred to storage.

The stripped mother liquor is returned to the regeneration section of the ion exchange unit for combination with other regenerant streams. Spent regenerant is treated to recover rejected phosphates, ammonia and potash. Potash is recovered from the spent regenerant by multiple effect evaporation/crystallization for recycle to the ion exchange regeneration circuit. Dicalcium phosphate is precipitated from the spent solution, which contains dissolved MAP and MKP, by reacting the solution with hydrated line. The dicalcium phosphate is recovered by centrifugation, dried in a conventional dryer and transferred to storage, from whence it can be sold as an important animal feed product or used as a high grade source of P_2O_5 for phosphoric acid production.

Ammonia is recovered from the spent regeneration solution which contains ammonium chloride from the ion exchange regeneration step by reaction with additional slaked lime. The recovered ammonia is recycled to the

ammoniation reactor and the residual calcium chloride solution, in the form of a brine, is routed to waste disposal, or for use as a road de-icing fluid.

Overall feedstock requirements for a 100 000 tonne per year MKP production rate and associate quantities of MAP and dicalcium phosphate are given in Table 3.1.

Extensive development work and pilot scale testing has been performed on the MAP production, Ion Exchange and MKP product recovery processes to demonstrate their viability and collect data for use in preparing detailed feasibility studies and in the design of a large scale demonstration or small scale commercial facility. All other process steps, including KCl Recovery, Dicalcium Phosphate and Ammonia Recovery and Product Drying, are considered to be commercially proven in similar industrial applications.

Pennzoil Process - Recycle Mode

An overall Block Flow Diagram for the Pennzoil Process - Recycle Mode is presented in Figure 3.3. In the process, which is the subject of numerous US and Canadian patents, potash is reacted with sulphuric acid at a temperature of 110-125°C to produce potassium bisulphate in an excess acid solution, according to the overall reaction.

$$KCl + H_2SO_4 \longrightarrow KHSO_4 + HCl$$

Hydrogen chloride evolved in the reaction is recovered as aqueous hydrochloric acid (20° or 22° Be), or potentially as anhydrons HCl, and stored for sale as an important by-product.

The potassium bisulphate/excess sulphuric acid solution is then reacted with phosphate rock to produce a potassium phosphate/phosphoric acid double salt, according to the overall simplified reaction.

$$Ca_9(PO_4)_6 + 3\,KHSO_4 + 6H_2SO_4 + 18H_2O \longrightarrow$$

$$3KH_2PO_4.H_3PO_4 + 9\,CaSO_4.2H_2O$$

Where $Ca_9(PO_4)_6$ is used to represent phosphate rock.

The reaction is carried out in a series of attack tanks similar to those used in a conventional wet process phosphoric acid plant. Waste gypsum and inert material from the phosphate rock are removed by filtration and discarded as in a conventional plant.

The potassium phosphate/phosphoric acid double salt is contacted with methanol to effect a separation of the double salt and precipitation of the monopotassium phosphate (MKP). The MKP is recovered by filtration, washed, dried and transferred to storage for sale as a high nutrient with a nominal 0-48-32 analysis.

Methanol is recovered from the methanol/phosphoric acid solution by conventional distillation and is recycled to the methanolic precipitation stage. Recovered phosphoric acid, containing a small quantity of residual potassium phosphate, is recycled to the potassium phosphate production unit (phosphate rock attack tanks) for conversion to potassium phosphate.

Overall feedstock requirements for a 100 000 tonne per year MKP production facility are given in Table 3.1.

Standard grade potash and phosphate rock (68% BPL) are the preferred raw materials for the potassium phosphate process. Lower grade potash could potentially be used but there is some concern that a high sodium content would affect product quality (in the form of sodium phosphate) and possibly the phase chemistry of the potassium phosphate/phosphoric acid system. Similarly, lower quality phosphate rock could be used although this is not considered to be economically attractive as higher raw

materials shipping costs per unit P_2O_5 would offset savings in minesite raw materials costs. Smelter grade sulphuric acid, 93-96%, is considered adequate for use in the process as long as the acid does not contain high concentrations of metallic contaminants.

The production of potassium bisulphate from potash and sulphuric acid and potassium phosphate/phosphoric acid double salt from potassium bisulphate, sulphuric acid and phosphate rock has been demonstrated by Pennzoil in a semi-commercial plant (50 tonnes per day P_2O_5, 15 tonnes per day K_2O capacity) at Hanford, California. In that operation the double salt was ammoniated to produce an 8-48-12 grade fertilizer. Methanolic precipitation of the MKP has been investigated by Pennzoil in laboratory scale equipment to determine key process parameters. In addition, methanolic precipitation of potassium phosphates was demonstrated briefly in a commercial scale plant by Goulding Fertilizers of Ireland in the 1950's. Pennzoil has since acquired rights to the Goulding Technology.

Pennzoil has no plans for further development of the potassium phosphate technology. However, Phosphate Engineering and Construction Co. (PECO) has recently entered into an agreement with Pennzoil for the development of commercialization prospects for the technology.

Pennzoil Process - Once Through Mode

An overall Block Flow Diagram for the Pennzoil Process - Once Through Mode is presented in Figure 3.4 and overall feedstock requirements for a 100 000 tonne per year MKP production rate are given in Table 3.1.

The Once Through Mode of operation is similar to that of the Recycle Mode except that the phosphoric acid recovered in the methanol/phosphoric acid distillation unit is processed further for sale as an important co-product rather than being recycled. In the option considered in this study, the phosphoric acid is ammoniated to produce monoammonium phosphate (MAP), a commodity fertilizer used in Canada as a

source of N and P nutrients. Alternatively, diammonium phosphate (DAP) can be produced for export as an important commodity fertilizer.

In another process option, the phosphoric acid from the methanol/phosphoric acid separation unit can be processed in an ion exchange purification unit to produce a high purity technical grade phosphoric acid for sale as a commodity chemical. Rejected phosphoric acid, containing residual potassium phosphates and other impurities, would be recycled to the potassium phosphate production unit for reuse.

Stage of development of the Once Through Mode is similar to that of the Recycle Mode as discussed earlier. Recovery of technical grade phosphoric acid from the co-produced impure phosphoric acid stream can be accomplished using commercially available technology which was developed to produce technical or feed grade phosphoric acid from wet process material. Recoveries should be higher than with wet process acid as the impurity level of the wet process phosphoric acid is higher than that expected in the co-produced phosphoric acid of the Pennzoil Process.

Process Comparison

During the evaluation of the PCS/PECO and Pennzoil processes, a number of advantages and disadvantages of each process became apparent, as highlighted in this section of the report.

The PCS/PECO High Temperature Melt Process is a simple process with a minimum of operating steps and, as such, its operation should be straight forward. High quality monopotassium phosphate (MKP) product is produced and high purity hydrochloric acid, either aqueous or anhydrous HCl, is recovered as a valuable by-product. The process has some flexibility as, with only minor circuit and operating changes, it can produce either MKP or potassium metaphosphate, a high grade slow release fertilizer. Additional flexibility can be built into the plant if excess capacity is built into the phosphate rock acidulation unit (the Nissan Hemihydrate Process in this study), resulting in the net

production of wet process phosphoric acid. This product can either be sold directly as merchant grade acid or ammoniated to produce monoammonium phosphate (MAP) or diammonium phosphate (DAP), both commodity fertilizers.

The PCS/PECO Ion Exchange Process is also a somevhat flexible process as it produces a lov grade MAP (containing some ammoniated metallic phosphates and some residual KCl) and dicalcium phosphate in addition to the main MKP product. The MAP can be marketed locally as a N-P fertilizer whereas the dicalcium phosphate is a commodity animal feed supplement, or can be utilized as a high grade feedstock in the production of phosphoric acid. However, it is a complex process involving a number of processing steps with large recycle streams and several evaporation, crystallization and filtration or centrifugation operations. Additionally, the chloride contained in the potash feedstream is discarded as vaste calcium chloride solution rather than being recovered as valuable hydrochloric acid. Disposal of the vaste calcium chloride could be costly and in some areas could be considered an environmental hazard, unless part or all of it can be used as a road de-icer or dust suppressant.

The Pennzoil Process - Recycle and Once Through Modes of operation is a flexible process as, in addition to producing the main MKP product, it produces a phosphoric acid stream that can either be recycled for the production of additional potassium phosphate fertilizer or processed further for sale as merchant grade phosphoric acid, ammonium phosphate fertilizers or technical grade phosphoric acid. Additionally, high purity hydrochloric acid is recovered as a valuable by-product. However, potassium losses are high as it reacts with fluorine and silica in the phosphate rock to produce insoluble potassium fluosilicate K_2SiF_6 which is discarded with the waste gypsum and other inert materials. In addition, little experimental data is available to establish methanol losses in the methanolic precipitation and recovery steps. Higher than expected methanol losses could lead to increased operating cost and possibly even an environmental emission problem.

FIGURE 3.1
MONOPOTASSIUM PHOSPHATE PROCESS
PCS/PECO HIGH TEMP. MELT PROCESS

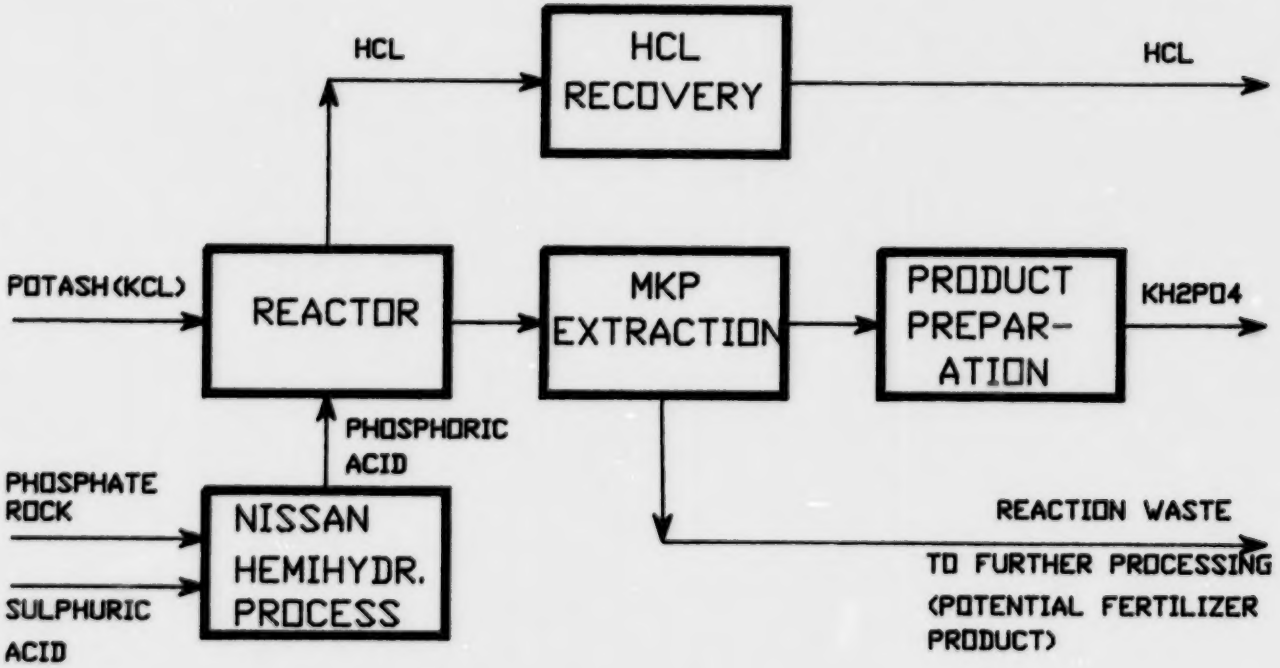

FIGURE 3.2
MONOPOTASSIUM PHOSPHATE PROCESS
PCS/PECO ION EXCHANGE PROCESS

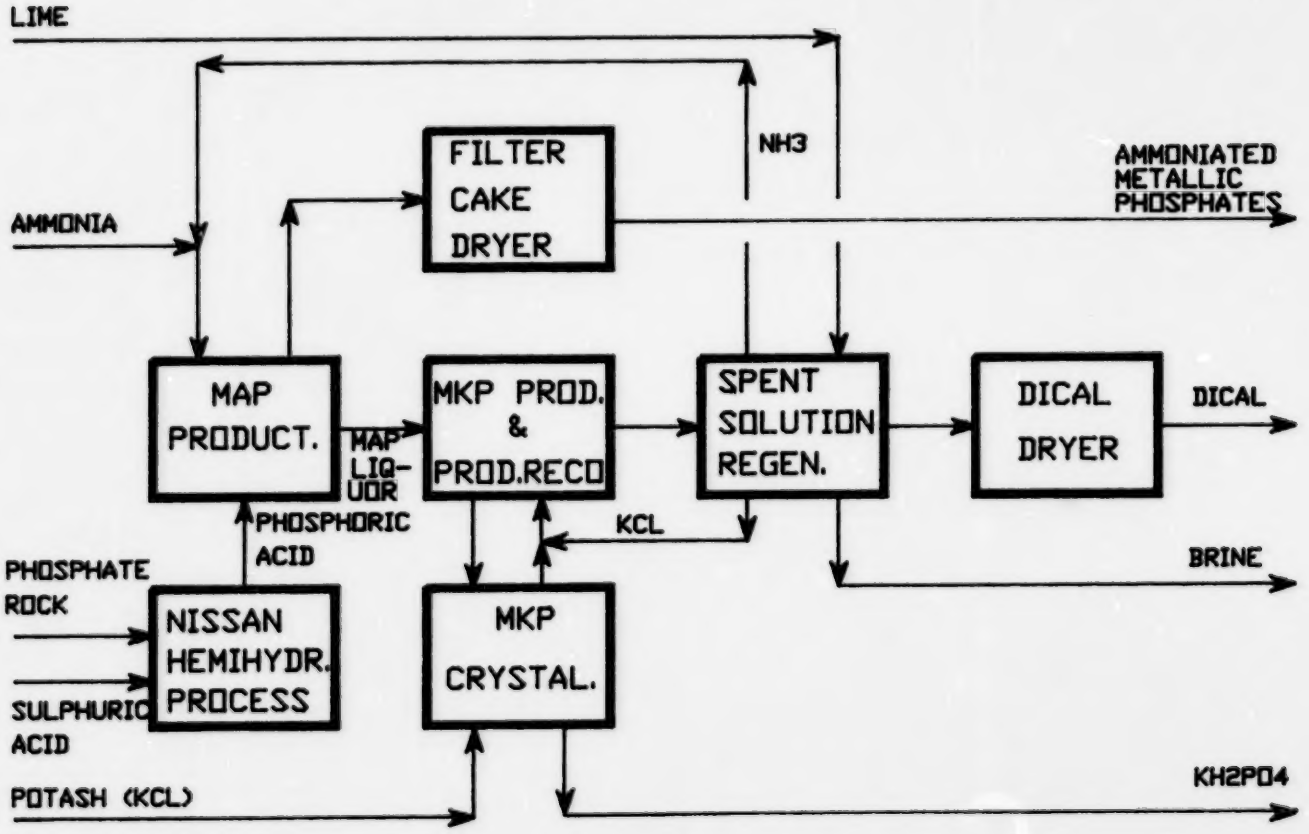

FIGURE 3.3

MONOPOTASSIUM PHOSPHATE PROCESS

PENNZOIL PROCESS - RECYCLE MODE

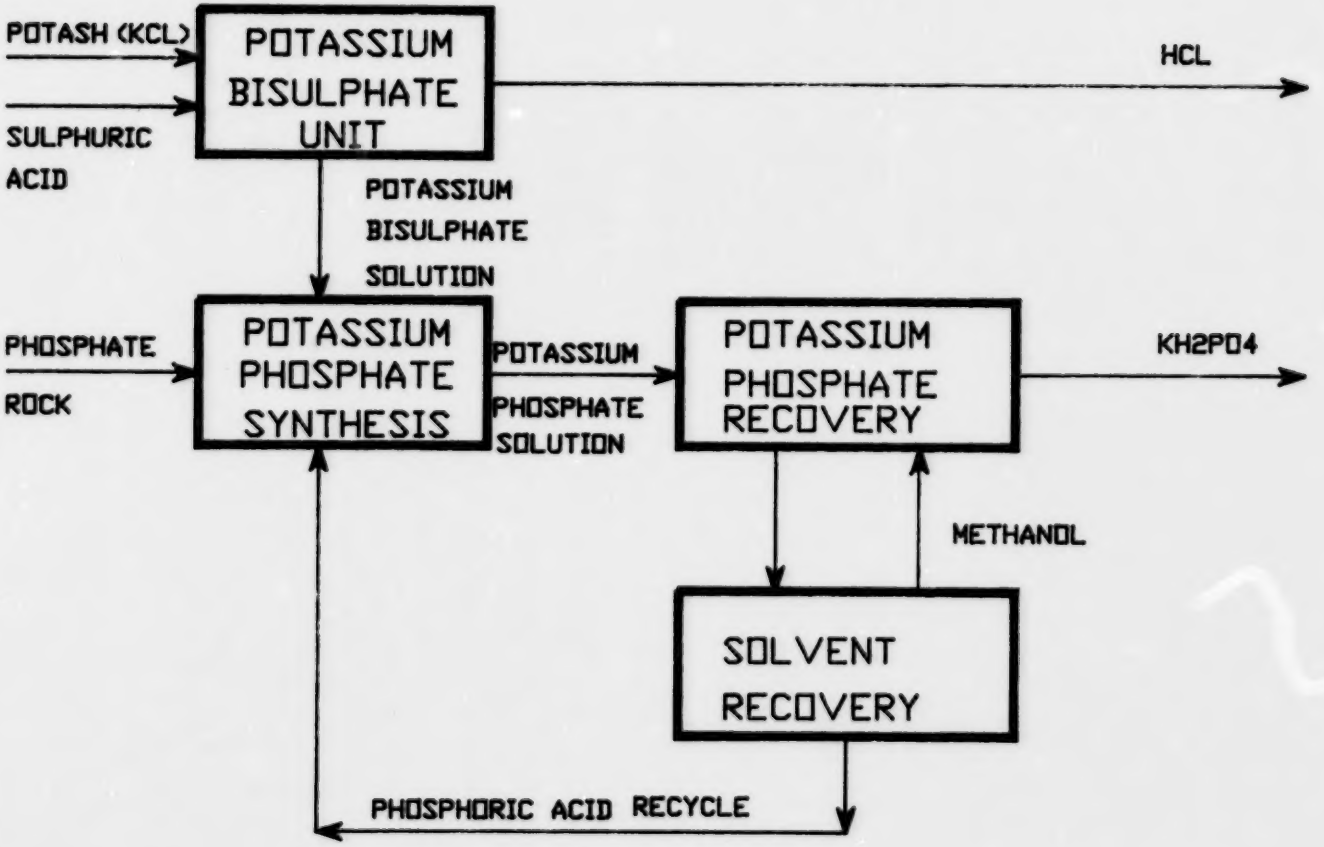

FIGURE 3.4

MONOPOTASSIUM PHOSPHATE PROCESS
PENNZOIL PROCESS - ONCE THROUGH MODE

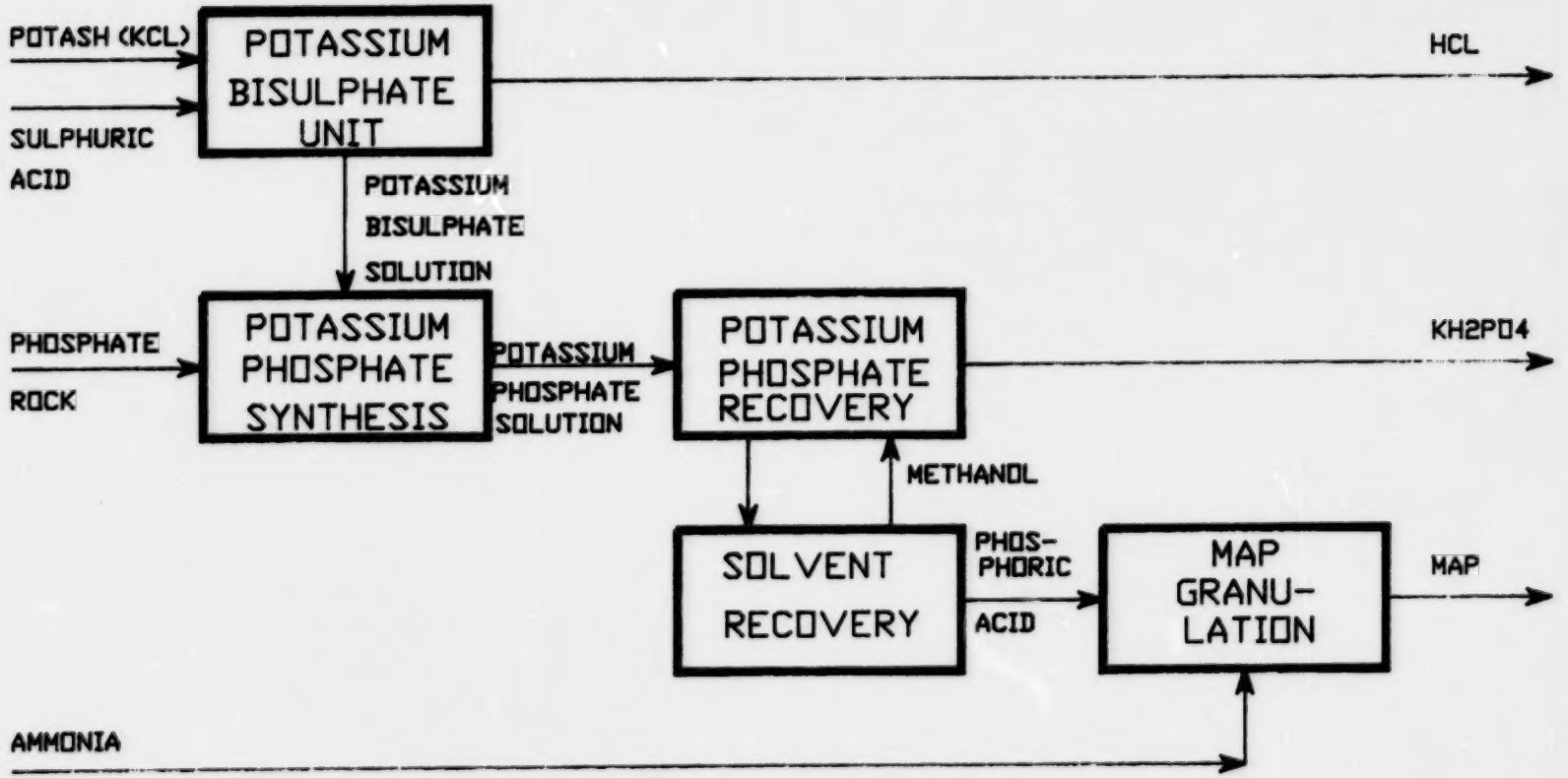

TABLE 3.1

TECHNICAL SUMMARY TABLE

(THOUSAND TONNE/YEAR)

RAW MATERIAL:	PCS/PECO HIGH TEMP BASE CASE	PCS/PECO ION EXCH	PENNZOIL RECYCLE	PENNZOIL ONCE THRU
POTASH (KCL)	60	83	58	64
PHOSPHATE ROCK (68% BPL)	184	260	185	446
SULPHURIC ACID (98%)	164	231	143	347
LIME	--	34	--	--
AMMONIA	--	3	--	18
PRODUCT:				
MONOPOTASSIUM PHOSPHATE (MKP)	100	100	100	100
HCL	28	--	32	32
MONOAMMONIUM PHOSPHATE (MAP)	--	28 *	--	136
DICALCIUM PHOSPHATE	--	31	--	--

* AMMONIATED METALLIC PHOSPHATES

3.3 SOURCES OF SULPHUR

A number of sources of sulphur are potentially available for use in an Atlantic Canada potassium phosphate fertilizer complex. As the PCS/PECO and Pennzoil Processes evaluated for the production of potassium phosphate fertilizers from potash and phosphate rock all require sulphur in the form of sulphuric acid, these sources of sulphur must be economically recoverable as sulphuric acid.

Potentially available sources of sulphur in Atlantic Canada include:

- Sulphur Dioxide from thermal power plant stack gases or base metal smelter off gases.

- Elemental sulphur from local petroleum refineries or offshore.

- Pyrite

- Gypsum, either native or phosphogypsum from an existing or proposed phosphate fertilizer complex.

- Purchased sulphuric acid from other regions of Canada or offshore.

Sulphuric acid is traditionally produced from elemental sulphur or from sulphur dioxide recovered from base metal smelter flue gas streams. The majority of sulphuric acid produced in Eastern Canada is from base metal smelter gases. Producers include INCO, Falconbridge, Noranda in Ontario, Quebec and New Brunswick. Elemental sulphur produced by Eastern Canadian petroleum refiners in Ontario, Quebec, New Brunswick and Nova Scotia is traditionally used in other applications including the pulp and paper industry. It could be used for the manufacture of sulphuric acid if the demand could not be met by smelter acid.

Sulphuric acid can be produced from sulphur dioxide recovered from thermal power plant flue gas streams. However, as the SO_2 content of the flue gas stream is much lower then that of a base metal smelter or

that contained in the SO_2 gas stream of a sulphur fed acid plant, recovery cost is very high and normally uneconomic. Estimated cost of sulphuric acid produced in this manner is at least double that of acid produced from elemental sulphur or base metal smelter sulphur dioxide.

Sulphur dioxide for the production of sulphuric acid can be recovered from iron pyrites by roasting. Additionally, sulphur dioxide can be produced from gypsum, either native or phosphogypsum from a wet process phosphoric acid plant, and coke with lime or cement being recovered as a byproduct. Neither technology appears to be attractive, however, as the estimated cost of sulphuric acid is quite high even with low value pyrite or gypsum.

Production costs for sulphuric acid from these sources of sulphur, F.O.B. Plantsite, are:

From pyrites:	$ 70-100 per tonne
From gypsum:	$120-180 per tonne
From sulphur:	$ 50- 60 per tonne (sulphur at $100-120 per tonne)
From smelter:	(assuming zero value SO_2).

The current competitive price for bulk quantities of smelter sulphuric acid in Atlantic Canada is $40-60 per tonne depending on consumer location, source of the acid and availability of the acid. Sulphuric acid produced from sulphur at $100-120 per tonne would be competitive with smelter acid at $60 per tonne as only 0.32 tonne of sulphur is used per tonne of 96% of sulphuric acid. Its potential production tends to regulate the upper limit for the price of smelter acid.

4.0 FINANCIAL EVALUATION

4.1 CAPITAL COST ESTIMATES

Capital cost estimates were developed for the four monopotassium phosphate (MKP) processes evaluated in this report:

- PCS/PECO High Temperature Melt Process
- PCS/PECO Ion Exchange Process
- Pennzoil Process - Recycle Mode
- Pennzoil Process - Once Through Mode

The capital cost estimates are presented in Tables 4.1 to 4.8 for the four cases and are summarized as follows:

		PCS/PECO HI TEMP	PCS/PECO ION EXCH	PENNZOIL RECYCLE	PENNZOIL ONCE THRU
Direct Costs,	$M	45.1	69.6	48.1	52.8
Indirect Costs,	$M	17.2	26.4	18.3	20.0
Other Costs,	$M	-	0.1	-	-
Owner's Costs,	$M	2.7	3.8	2.7	2.7
Total Project Cost,	**$M**	**65.0**	**99.9**	**69.1**	**75.5**

All costs are in fourth quarter 1987 Canadian dollars, Atlantic Canada location.

Battery limits costs for the PCS/PECO High Temperature Melt Process and the PCS/PECO Ion Exchange Process were factored from cost information contained in the confidential reports provided to Kilborn by PCS. These costs, in 1987 US dollars, were converted to Canadian dollars ($1.00 US = $1.30 Cdn) and adjusted for plant size and location using standard cost-capacity and labour productivity factors. Additional costs were included for raw materials unloading storage, product storage and loadout, cooling tower, effluent water treatment and waste disposal, based on Kilborn in-house information.

Direct costs for the Nissan Hemihydrate Process (for the production of phosphoric acid from phosphate rock for use in both PCS/PECO processes) were developed from Kilborn in-house information. Offsite and utility system costs for the Nissan Process were integrated into those for the overall processing facility.

Direct costs for the Pennzoil Process - Recycle and Once Through Modes of operation were factored from Kilborn in-house information developed from previous Pennzoil technology studies (1981-1985). These costs were updated to a 1987 cost basis using appropriate Chemical Engineering Plant Cost Indices and adjusted for plant size and location using standard cost-capacity and labour productivity factors.

Indirect costs include home office engineering and construction management costs at 15 percent of total direct costs and project contingency at 20 percent of total direct costs plus home office costs. Other costs include allowances for initial catalyst and chemicals costs. Owner's costs include allowances for Owner's engineering, environmental and permitting costs, start-up costs and spare parts inventory.

No allowances have been made for unusual infrastructure costs, such as rail access, poor soil condition costs, unexpected environmental regulation costs or remote site costs, or for licensing and royalty fees.

TABLE 4.1

CAPITAL COST FOR MKP PLANT

PCS/PECO HIGH TEMP. MELT PROCESS
(INCLUDING NISSAN HEMIHYDRATE P2O5 PLANT)

CAPITAL COST ESTIMATE

		1987 CAN K$
DIRECT COST		
PROCESS UNITS		31600
OTHER SERVICES		13500
TOTAL DIRECT COST		45100
INDIRECT COSTS		
ENGIN, CONST %	15	6800
CONTING. %	20	10400
TOTAL INDIRECT COST		17200
TOTAL PLANT & EQUIP		62300
CATALYST & CHEM INIT.		40
OWNER'S COSTS AND MISC.		2700
TOTAL ESTIMATED COST		65000

TABLE 4.2

CAPITAL COST FOR MKP PLANT

PCS/PECO HIGH TEMP. MELT PROCESS
(INCLUDING NISSAN HEMIHYDRATE P2O5 PLANT)

DIRECT COST ESTIMATE

DIRECT COST		
PROCESS UNITS		1987 CAN K$
	REACTION	5346
	DISSOL/FILTRAT	3001
	CRYSTALLIZATION	3491
	PRODUCT DRYER	307
	HCL RECOVERY	1471
	NISSAN P2O5 PLANT	18000
	TOTAL DIR-PROCESS	31600
OTHER SERVICES		
	PRODUCT STORAGE	3714
	RAILCAR LOAD	210
	RAW MAT STORAGE	3000
	COOLING TOWER	914
	EFFLU. WATER TREAT	1249
	BUILDINGS	780
	UTILITIES & SERV	3500
	SITE DEVELOP.	130
	TOTAL DIR-OTHERS	13500

TABLE 4.3

CAPITAL COST FOR MKP PLANT

PCS/PECO ION EXCHANGE PROCESS
(INCLUDING NISSAN HEMIHYDRATE P2O5 PLANT)

CAPITAL COST ESTIMATE

		1987 CAN K$
DIRECT COST		
PROCESS UNITS		52400
OTHER SERVICES		17200
TOTAL DIRECT COST		69600
INDIRECT COST		
ENGIN, CONST %	15	10400
CONTING. %	20	16000
TOTAL INDIRECT COST		26400
TOTAL PLANT & EQUIP		96000
CATALYST & CHEM INIT.		80
OWNER'S COSTS AND MISC.		3800
TOTAL ESTIMATED COST		99900

TABLE 4.4

CAPITAL COST FOR MKP PLANT

PCS/PECO ION EXCHANGE PROCESS
(INCLUDING NISSAN HEMIHYDRATE P205 PLANT)

DIRECT COST ESTIMATE

		1987 CAN K$
DIRECT COST		
PROCESS UNITS		
	MAP REACT	1771
	CLARIFICATION	11543
	MKP CRYSTAL	5175
	KCL REGEN	6893
	DICAL RECOVERY	2774
	DICAL DRYING	399
	MAP DRYING	1107
	MKP DRYING	615
	NISSAN P205 PLANT	22142
	TOTAL DIR-PROCESS	52400
OTHER SERVICES		
	PRODUCT STORAGE	4230
	RAILCAR LOAD	210
	RAW MAT STORAGE	4500
	COOLING TOWER	1124
	EFFLU. WATER TREAT	1536
	BUILDINGS	1000
	UTILITIES & SERV	4428
	SITE DEVEL	185
	TOTAL DIR-OTHERS	17200

TABLE 4.5

CAPITAL COST FOR MKP PLANT

PENNZOIL PROCESS - RECYCLE MODE
(INCLUDING PENNZOIL KHSO4 PLANT)

CAPITAL COST ESTIMATE

		1987 CAN K$
DIRECT COST		
PROCESS UNITS		35100
OTHER SERVICES		13000
TOTAL DIRECT COST		48100
INDIRECT COST		
ENGIN, CONST %	15	7200
CONTING. %	20	11100
TOTAL INDIRECT COST		18300
TOTAL PLANT & EQUIP		66400
CATALYST & CHEM INIT.		40
OWNER'S COSTS AND MISC.		2700
TOTAL ESTIMATED COST		69100

KILBORN

TABLE 4.6

CAPITAL COST FOR MKP PLANT

PENNZOIL PROCESS - RECYCLE MODE
(INCLUDING PENNZOIL KHSO4 PLANT)

DIRECT COST ESTIMATE

DIRECT COST		
PROCESS UNITS		1987 CAN K$
	BISULPHATE	3258
	KH2PO4	15975
	METHANOL	14398
	HCL RECOVERY	1471
	TOTAL DIR-PROCESS	35100
OTHER SERVICES		
	PRODUCT STORAGE	3783
	RAILCAR LOAD	210
	RAW MAT STORAGE	1892
	COOLING TOWER	176
	EFFLU. WATER TREAT	805
	BUILDINGS	841
	UTILITIES & SERV	4459
	SITE DEVEL	841
	TOTAL DIR-OTHERS	13000

TABLE 4.7

CAPITAL COST FOR MKP PLANT

PENNZOIL PROCESS - ONCE THROUGH MODE
(INCLUDING PENNZOIL KHSO4 PLANT)

DIRECT COST ESTIMATE

		1987 CAN K$
DIRECT COST		
PROCESS UNITS		38000
OTHER SERVICES		14800
TOTAL DIRECT COST		52800
INDIRECT COST		
ENGIN, CONST %	15	7900
CONTING. %	20	12100
TOTAL INDIRECT COST		20000
TOTAL PLANT & EQUIP		72800
CATALYST & CHEM INIT.		40
OWNER'S COSTS AND MISC.		2700
TOTAL ESTIMATED COST		75500

TABLE 4.8

CAPITAL COST FOR MKP PLANT

PENNZOIL PROCESS - ONCE THROUGH MODE
(INCLUDING PENNZOIL KHSO4 PLANT)

DIRECT COST ESTIMATE

DIRECT COST		1987 CAN K$
PROCESS UNITS		
	BISULPHATE	3258
	KH2PO4	15975
	METHANOL	14398
	MAP GRANULATION	2943
	HCL RECOVERY	1471
	TOTAL DIR-PROCESS	38000
OTHER SERVICES		
	PRODUCT STORAGE	3783
	RAILCAR LOAD	210
	RAW MAT STORAGE	3053
	COOLING TOWER	176
	EFFLU. WATER TREAT	805
	BUILDINGS	841
	UTILITIES & SERV	5053
	SITE DEVEL	841
	TOTAL DIR-OTHERS	14800

4.2 OPERATING COST ESTIMATES

Operating cost estimates were developed for the four monopotassium phosphate (MKP) processes evaluated in this report.

- PCS/PECO High Temperature Melt Process
- PCS/PECO Ion Exchange Process
- Pennzoil Process - Recycle Mode
- Pennzoil Process - Once Through Mode

Operating cost parameters are presented in Table 4.9 and operating cost estimates are presented in Tables 4.10 to 4.13 for the four cases, as summarized below:

		PCS/PECO HI TEMP	PCS/PECO ION EXCH	PENNZOIL RECYCLE	PENNZOIL ONCE THRU
Raw Materials,	$M/yr	24.8	37.6	23.4	53.5
Utilities,	$M/yr	1.9	5.3	5.7	7.1
Labour & Maint,	$M/yr	5.1	8.1	5.5	6.3
Overheads,	$M/yr	2.6	4.0	2.8	3.0
Total Op. Cost,	**$M/yr**	**34.5**	**55.0**	**37.3**	**69.8**

Raw materials costs were based on information provided by McAllister Environmental Services Ltd. of Calgary for fertilizer materials and on Kilborn in-house information for other materials.

The price of New Brunswick potash delivered by rail to a plant in Nova Scotia was set at $90 per tonne, reflecting the current price for standard grade potash at a deep water port in New Brunswick or Nova Scotia. The price of 68% BPL phosphate rock was set at $52 per tonne delivered to the plant in Nova Scotia from the US Gulf or Atlantic Coast, based on $28.50 US per tonne FOB Port plus a transportation

allowance of $15 Cdn per tonne. A price of $200 per tonne was selected for ammonia, based on a current US Gulf Coast price of $108 US plus a transportation allowance of $60 Cdn per tonne.

The price of sulphuric acid was set at $60 per tonne for 96% acid delivered to the plant, representative of the current price of smelter acid in Atlantic Canada. This should be considered an upper limit for the cost of sulphuric acid for the phosphate fertilizer complex as it could be produced from elemental sulphur at $100-120 per tonne for this cost. A price of $60 per tonne was selected for lime which is used in the PCS/PECO Ion Exchange Process for the recovery of ammonia and phosphate and the rejection of chlorides as calcium chloride.

Fuel oil for use in the fertilizer complex was priced at $175 per cubic metre ($27.75 per barrel), electricity was priced at 4¢ per KWH and steam was priced at $17.50 per tonne ($8.00 per 1000 pounds).

Operating labour costs were based on a preliminary operating staff count for each process and an average labour cost of $21.50 per hour ($44,000 per year). The cost of operating supplies was set at 15 percent of the operating labour cost and annual maintenance cost was set at 5 percent of the capital cost of the facility. Plant overhead costs were estimated to be 3 percent of the capital cost per year and plant insurance and local taxes were set at one percent of the capital cost per year.

All costs are in fourth quarter 1987 Canadian dollars, Atlantic Canada location. Raw material prices, where indicated, were converted from $US to $Cdn using $1.00 US = $1.30 Cdn.

KILBORN

TABLE 4.9

PRODUCTION COST PARAMETERS

RAW MATERIAL:	CAN $/TONNE	
POTASH (KCL)	90	
PHOSPHATE ROCK (68% BPL)	52	
SULPHURIC ACID (98%)	60	
LIME	60	
AMMONIA	200	
UTILITIES:		
FUEL OIL	175.00	CAN $/ M3
ELECTRICITY	0.04	CAN $/KWH
PROCESS WATER	0.07	CAN $/M3
COOLING WATER	0.05	CAN $/M3
STEAM	17.50	CAN $/TONNE
OPERATING LABOUR	21.50	CAN $/HR
OPERATING SUPPLIES	15	% OF OP LAB
MAINTENANCE	5	% CAP. COST
PLANT OVHD	3	% CAP. COST
INSURANCE/TAXES	1	% CAP. COST
OPERATION FACTOR	330	DAYS/YEAR
1 US $	1.3	CAN $

KILBORN

TABLE 4.10

PRODUCTION COST FOR MKP PLANT

PCS/PECO HIGH TEMP. MELT PROCESS
(INCLUDING NISSAN HEMIHYDRATE P2O5 PLANT)

ANNUAL PRODUCTION 100000 TONNE MKP/YR

CAPITAL COST (1987) 65000 CAN K$

RAW MATERIAL	UNIT COST	UNITS	PRODUCTION COST CAN K $/YR (1987)
KCL	90.00 CAN $/TONNE	182.3 TONNE/DAY	5413
PHOSPHATE ROCK	52.00 CAN $/TONNE	558.2 TONNE/DAY	9578
H2SO4 ACID	60.00 CAN $/TONNE	496.6 TONNE/DAY	9833
			24824
UTILITIES			
ELECTRICITY	0.04 CAN $/KWH	157 KWH/TONNE MKP	628
STEAM	17.50 CAN $/TONNE	52 TPD(M)/TPD(M)	298
FUEL OIL	175 CAN $/M3	0.047 M3/TONNE MKP	818
PROCESS WATER	0.07 CAN $/M3	1 M3/TONNE MKP	9
COOLING WATER	0.05 CAN $/M3	37 M3/TONNE MKP	185
			1938
OPERATING LABOR	21.5 CAN $/MH	36 STAFF	1610
OPERATING SUPPLIES	15 % OP. LAB		241
MAINTENANCE	5 %CAP.COST		3250
			5101
PLANT OVHD	3 %CAP.COST	PER YR	1950
INSURANCE/TAXES	1 %CAP.COST	PER YR	650
			2600
TOTAL PRODUCTION COST			34463

TABLE 4.11

PRODUCTION COST FOR MKP PLANT

PCS/PECO ION EXCHANGE PROCESS
(INCLUDING NISSAN HEMIHYDRATE P2O5 PLANT)

ANNUAL PRODUCTION 100000 TONNE MKP/YR

CAPITAL COST (1987) 99900 CAN K$

RAW MATERIAL	UNIT COST	UNITS	PRODUCTION COST CAN K $/YR (1987)
KCL	90.00 CAN $/TONNE	252.0 TONNE/DAY	7484
PHOSPHATE ROCK	52.00 CAN $/TONNE	788.3 TONNE/DAY	13527
H2SO4 ACID	60.00 CAN $/TONNE	701.3 TONNE/DAY	13886
LIME (CAO)	60.00 CAN $/TONNE	103.9 TONNE/DAY	2057
AMMONIA (NH3)	200.00 CAN $/TONNE	10.4 TONNE/DAY	689
			37643
UTILITIES			
ELECTRICITY	0.04 CAN $/KWH	285 KWH/TONNE MKP	1142
STEAM	17.50 CAN $/TONNE	533 TPD(M)/TPD(M)	3076
FUEL OIL	175 CAN $/M3	0.061 M3/TONNE MKP	1069
			5288
OPERATING LABOR	21.5 CAN $/MH	60 STAFF	2683
OPERATING SUPPLIES	15 % OP. LAB		402
MAINTENANCE	5 %CAP.COST		4995
			8081
PLANT OVHD	3 %CAP.COST	PER YR	2997
INSURANCE/TAXES	1 %CAP.COST	PER YR	999
			3996
TOTAL PRODUCTION COST			55008

TABLE 4.12

PRODUCTION COST FOR MKP PLANT

PENNZOIL PROCESS - RECYCLE MODE
(INCLUDING PENNZOIL KHSO4 PLANT)

ANNUAL PRODUCTION 100000 TONNE MKP/YR

CAPITAL COST (1987) 69100 CAN K$

RAW MATERIAL	UNIT COST	UNITS	PRODUCTION COST CAN K $/YR (1987)
KCL	90.00 CAN $/TONNE	175.0 TONNE/DAY	5198
PHOSPHATE ROCK	52.00 CAN $/TONNE	560.0 TONNE/DAY	9610
H2SO4 ACID	60.00 CAN $/TONNE	434.0 TONNE/DAY	8593
			23400
UTILITIES			
ELECTRICITY	0.04 CAN $/KWH	150 KWH/TONNE MKP	600
STEAM	17.50 CAN $/TONNE	496 TPD(M)/TPD(M)	2865
FUEL OIL	175 CAN $/M3	0.111 M3/TONNE MKP	1944
PROCESS WATER	0.07 CAN $/M3	1.6 M3/TONNE MKP	11
COOLING WATER	0.05 CAN $/M3	49 M3/TONNE MKP	246
			5666
OPERATING LABOR	21.5 CAN $/MH	40 STAFF	1709
OPERATING SUPPLIES	15 % OP. LAB		268
MAINTENANCE	5 %CAP.COST		3455
			5512
PLANT OVHD	3 %CAP.COST	PER YR	2073
INSURANCE/TAXES	1 %CAP.COST	PER YR	691
			2764
TOTAL PRODUCTION COST			37343

TABLE 4.13

PRODUCTION COST FOR MKP PLANT

PENNZOIL PROCESS - ONCE THROUGH MODE
(INCLUDING PENNZOIL KHSO4 PLANT)

ANNUAL PRODUCTION 100000 TONNE MKP/YR

CAPITAL COST (1987) 75500 CAN K$

RAW MATERIAL	UNIT COST	UNITS	PRODUCTION COST CAN K $/YR (1987)
KCL	90.00 CAN $/TONNE	195.0 TONNE/DAY	5792
PHOSPHATE ROCK	52.00 CAN $/TONNE	1350.0 TONNE/DAY	23166
H2SO4 ACID	60.00 CAN $/TONNE	1050.0 TONNE/DAY	20790
AMMONIA	200.00 CAN $/TONNE	56.0 TONNE/DAY	3696
			53444
UTILITIES			
ELECTRICITY	0.04 CAN $/KWH	171 KWH/TONNE MKP	684
STEAM	17.50 CAN $/TONNE	611 TPD(M)/TPD(M)	3529
FUEL OIL	175 CAN $/M3	0.150 M3/TONNE MKP	2625
PROCESS WATER	0.07 CAN $/M3	1.6 M3/TONNE MKP	11
COOLING WATER	0.05 CAN $/M3	50 M3/TONNE MKP	248
			7096
OPERATING LABOR	21.5 CAN $/MH	48 STAFF	2147
OPERATING SUPPLIES	15 % OP. LAB		322
MAINTENANCE	5 %CAP.COST		3775
			6244
PLANT OVHD	3 %CAP.COST	PER YR	2265
INSURANCE/TAXES	1 %CAP.COST	PER YR	755
			3020
TOTAL PRODUCTION COST			69803

4.3 PRODUCT REVENUE ESTIMATES

Product revenue estimates were prepared for the four monopotassium phosphate (MKP) processes, as presented in Table 4.14:

	PRODUCT REVENUE $M/YR
PCS/PECO High Temp Melt Process	36.5
PCS/PECO Ion Exchange Process	45.6
Pennzoil Process - Recycle Mode	37.3
Pennzoil Process - Once Through Mode	71.2

Estimated product prices were based on information provided by McAllister Environmental for fertilizer materials and on Kilborn in-house information for by-product hydrochloric acid.

As monopotassium phosphate is not currently produced in bulk quantities for the fertilizer industry, its price is not established in the market place. As such, a competitive price was determined based on its K and P content relative to potash as the source of K and triple superphosphate (TSP) or diammonium phosphate (DAP) less its N value as the source of P. With premium grade potash at $100 per tonne and TSP at $208 per tonne, the competitive price for MKP is $300 per tonne as a unit of MKP contains approximately 60 percent of the nutrient value of a unit of potash plus 115 percent of the nutrient value of a unit of TSP. This competitive price for MKP contains no premium for its chloride-free quality compared to potash.

If MKP is priced competitively with potassium sulphate as the source of chloride-free K and TSP or DAP as the source of P, a price of $350 per tonne results as the price of potassium sulphate is 2-3 times that of potash on K-equivalent bases. The impact of this premium price on the financial potential of the project is discussed in the Financial Evaluation section which follows.

The price of monoammonium phosphate (MAP) was set at $250 per tonne based on a current US price of $180-200 US, FOB Florida port. For the PCS/PECO Ion Exchange Process, the price of MAP was discounted to $225 per tonne as this material contains ammoniated metallic phosphates as well as MAP. It should be noted that exports of MAP are minor; thus, the co-production of diammonium phosphate (DAP) should be considered if export markets are of importance.

A price of $300 per tonne was established for feed grade dicalcium phosphate based on a current US price of $250 US per tonne, FOB Florida port and a $25 per tonne discount for quality.

Hydrochloric acid was priced at $230 per tonne of HCl ($70-80 per tonne of 20-22°Be acid), based on current retail prices of $150-180 per tonne for truckload quantities delivered to a customer's plant. Hydrochloric acid is used in the metal, chemical, food and petroleum industries. Major uses are in steel pickling, in oxychlorination chemical reactions and in oil and gas well acidulation. Other uses include the production of a wide range of metallic chlorides, the acidulation of phosphate rock to produce high grade phosphoric acid and the cleaning of food plant equipment and lines. Recovery of the HCl as anhydrons HCl is also potentially possible. However, it is normally used within the producing complex or marketed locally to a dedicated user and, therefore, was not considered as a marketable form in this study.

TABLE 4.14

PRODUCT REVENUE ESTIMATES

PRODUCT COST PARAMETERS:	CAN $/TONNE
MONOPOTASSIUM PHOSPHATE (MKP)	300
HCL	230
MONOAMMONIUM PHOSPHATE (MAP)	250
AMMONIATED METALLIC PHOSPHATES	225
DICALCIUM PHOSPHATE	300

PRODUCTION, KTONNE/YEAR:	PCS/PECO HIGH TEMP BASE CASE	PCS/PECO ION EXCH	PENNZOIL RECYCLE	PENNZOIL ONCE THRU
MONOPOTASSIUM PHOSPHATE (MKP)	100	100	100	100
HCL	28	--	32	32
MONOAMMONIUM PHOSPHATE (MAP)	--	28 *	--	136
DICALCIUM PHOSPHATE	--	31	--	--
PRODUCT REVENUE, CAN K$/YR:				
MONOPOTASSIUM PHOSPHATE (MKP)	30000	30000	30000	30000
HCL	6500	--	7300	7300
MONOAMMONIUM PHOSPHATE (MAP)	--	6200 *	--	33900
DICALCIUM PHOSPHATE	--	9400	--	--
TOTAL REVENUE ESTIMATE	36500	45600	37300	71200

* AMMONIATED METALLIC PHOSPHATES

4.4 FINANCIAL EVALUATION

Because of the preliminary nature of the technology evaluation study, a financial analysis was not prepared. However, certain observations can be made on the financial potential of the various processes based on the capital, operating cost and product revenue estimates that were developed for the four processes:

		PCS/PECO HI TEMP	PCS/PECO ION EXCH	PENNZOIL RECYCLE	PENNZOIL ONCE THRU
Capital Cost,	$M	65.0	99.9	69.1	75.5
Production Revenue	$M/yr	36.5	45.6	37.3	71.2
Operating Cost	$M/yr	34.5	55.0	37.3	69.8
Gross Margin	$M/yr	2.0	Neg	0	1.4

It is evident that the PCS/PECO Ion Exchange Process is financially unattractive as the estimated operating cost is between $9 and $10 million per year higher than the estimated product revenue and the estimated capital cost is the highest of the four process options that were considered. The complexity of the process, the high losses of valuable rav materials and the rejection of the chloride content of the potash as vaste calcium chloride all contribute to the poor potential of the process. Recovery of the vaste calcium chloride for use as road de-icer would increase product revenue marginally but not to a sufficient extent to make the project financially attractive.

The Pennzoil Process - Recycle Mode has an estimated product revenue equal to the estimated operating cost. This process could become attractive if product revenues increase or if operating costs (primarily rav materials costs) decrease. With an increase in MKP price from $300 per tonne to $350 per tonne to reflect its desirable chloride-free properties, product revenue is increased by $5 million per year. Similarly, if the price of sulphuric acid is reduced from $60 per tonne

to $40 per tonne to reflect an over supply of smelter acid as a result of stricter SO_2 emission standards, the annual operating cost is reduced by $2.9 million.

The Pennzoil Process - Once Through Mode indicates the flexibility of the process as monoammonium phosphate (MAP) is co-produced with the MKP. Estimated annual product revenue is higher than the estimated operating cost by $1.4 million. The indicated gross margin would be increased, as discussed above, if the product MKP price is increased to reflect its superior quality or if the price of sulphuric acid is reduced. Additionally, the gross margin would be increased appreciably if technical grade phosphoric acid as produced instead of the MAP, as discussed in Section 3.2, as the selling price of technical grade phosphoric acid is substantially above that of fertilizer products.

The PCS/PECO High Temperature Melt Process has the highest indicated gross margin at $2.0 million per year and the lowest estimated capital cost at $65.0 million. Although not financially attractive at this gross margin, the Process appears to have a reasonable degree of potential. If the MKP price is increased to $350 per tonne as discussed earlier, a gross margin of $7.0 million per year results and a Payout Period of 9.3 years is indicated ($65.0 Million Capital cost divided by $7.0 Million per year Gross Margin). Although not evaluated in this study, the attractiveness of the process could possibly be improved if the size of the Phosphoric Acid Plant was increased so that a portion of the phosphoric acid could be used to produce a second product (monoammonium phosphate, diammonium phosphate or potentially technical grade phosphoric acid), as in the Pennzoil Process - Once Through Mode.

4.5 PRODUCT MARKET POTENTIAL

As indicated earlier, potassium phosphates are not currently produced in bulk quantities for the fertilizer industry due to their high cost relative to competitive potassium and phosphate fertilizers. Limited quantities of potassium phosphates are produced for chemical applications by the direct reaction between phosphoric acid and potassium hydroxide. However, their cost is in the order of $1000-1200 per tonne, much too high to be considered for fertilizer applications.

With the leading technologies evaluated in this study, it appears that potassium phosphate fertilizers can be produced from phosphate rock, potash and sulphuric acid at a price that is close to the competitive potash and phosphate fertilizer prices. As such, it should be possible to establish a long term market for potassium phosphate fertilizers that would take advantage of their superior qualities compared to the competitive potash and phosphate fertilizers, including their high nutrient value, chloride-free nature and excellent agronomic properties.

An apparent market for potassium phosphates in Canada would be as a replacement for potassium sulphate which is imported from the USA for use on chloride sensitive crops. As the cost of potassium sulphate is 2-3 times that of potash on a K-equivalent basis, potassium phosphates could realize a price premium of 20-30 percent in this application compared to the bulk fertilizer market. Imports of potassium sulphate in 1986, the last year for which information is available, were approximately 25 000 tonnes or 35 000 tonnes of potassium phosphate equivalent. Additionally, current consumption of potassium sulphate in the USA is in the range of 200 000-250 000 tonnes per year. A total of 300 000-400 000 tonnes per year of MKP would be required to replace potassium sulphate in this market. Competitively priced MKP from an Atlantic Canada plant should be able to compete favourably with potassium sulphate for the citrus crops in South Eastern USA.

Although firm projections cannot be made on the realistic market potential for potassium phosphate fertilizers, it is evident that the total production of 100 000 tonnes per year could be sold in Canada and the USA competitively with potassium sulphate as the source of chloride-free K. Similar markets should be available in Europe where the current sources of chloride-free K are potassium sulphate or potassium nitrate.

5.0 SOCIO ECONOMIC AND ENVIRONMENTAL ANALYSIS

5.1 SOCIO ECONOMIC PROFILE

A number of direct and indirect benefits to Atlantic Canada as a result of construction and operation of a potassium phosphate fertilizer complex in Cape Breton, Nova Scotia were identified, including:

- project related job creation
- supporting services job creation
- federal and provincial taxes
- reduced unemployment
- market diversification for the New Brunswick potash industry
- market opportunity for smelter sulphuric acid.

Construction of a potassium phosphate complex in Cape Breton would create 300-500 man years of direct employment in Atlantic Canada in engineering services, fabrication of equipment components for the plant and in construction labour to erect the plant facilities and associated buildings. In addition, an estimated 80 full time employees would be required to operate and maintain the fertilizer complex and market the products (40 operations, 30 maintenance, 10 administrative/marketing).

Additional jobs will be created, indirectly as a result of the project in supporting sectors, including the service, transportation, administration, trade and recreation industries. These spin-off jobs will be created to support the workers both on the job and at home. By using a direct employment multiplier of 1.0 for the Cape Breton region of Atlantic Canada, an equal number of indirect jobs will be created during both construction and operation of the plant.

Salaries earned by the estimated 80 plant employees and the additional 80 spin-off job employees will be spent in the local community and Atlantic Canada region to support the employees and their families. Federal and Provincial taxes will also be paid by these individuals. It is estimated that the average employee earning $40,000 per year will pay

$6,500 in federal income tax and $3,200 in provincial income tax. In addition, an estimated $2.0-3.2 million in federal income tax and $1.0-1.6 million in provincial income tax would be paid by direct and indirect workers during an 18-24 month construction period.

Given that the rate of unemployment is extremely high in Cape Breton, in the range of 15-20 percent, unemployment will be reduced as a result of construction and operation of the fertilizer complex. If unemployed persons are able to fill the majority of direct and indirect jobs created during operation of the plant, unemployment insurance benefits and welfare payments should be reduced by $1.2-1.6 million per year. A similar reduction should be realized during construction of the plant.

A potential benefit exists for potash producers in New Brunswick as the production of a higher nutrient value potassium phosphate fertilizer for export sale provides a small degree of product diversification. As such the wide fluctuations that are frequently experienced in potash demand many be dampened somewhat as demand for the high quality chloride-free potassium phosphate product may not be subject to these wide fluctuations. Additionally, because of its high nutrient value (80-90 percent), potassium phosphate fertilizers can be shipped long distances at a lower cost than for the competitive potash and triple superphosphate or diammonium phosphate.

Finally, the potassium phosphate plant provides a market opportunity for smelter sulphuric acid in Atlantic Canada. As more stringent SO_2 emission regulations are introduced in Canada, additional quantities of base metal smelter sulphuric acid will become available. As it is costly to ship corrosive sulphuric acid to distance markets, local surpluses may become available. Environment Canada officials have, in recent years, estimated surpluses of sulphuric acid in the range of 1.0-2.0 million tonnes per year with the introduction of new SO_2 emission regulations. The proposed potassium phosphate fertilizer complex would consume 160 000-240 000 tonnes per year of sulphuric acid. This could be supplied by base metal smelters in Quebec or New Brunswick, including Noranda from a new large-scale sulphuric and plant currently being constructed at Rouyn-Noranda, Quebec.

5.2 ENVIRONMENTAL OVERVIEW

The potassium phosphate fertilizer complex is expected to include plants for the production of wet process phosphoric acid, directly in the PCS/PECO cases and indirectly in the Pennzoil cases, monopotassium phosphate and potentially other fertilizer or feed grade products.

In the PCS/PECO High Temperature Melt Process, phosphoric acid is produced from phosphate rock and sulphuric acid, probably imported as by-product acid from a base metal smelter. The process generates solid waste phosphogypsum. Potassium phosphate fertilizer is produced from the phosphoric acid and potash imported from New Brunswick. Hydrogen chloride, evolved during the potassium phosphate production step, is recovered as hydrochloric acid.

In the Pennzoil Process, potash is reacted with sulphuric acid to produce potassium bisulphate and by-product hydrochloric acid. The potassium bisulphate and excess sulphuric acid are reacted with phosphate rock to produce a potassium phosphate/phosphoric acid double salt and waste phosphogypsum. Methanol is used to separate monopotassium phosphate from the double salt, with the co-produced phosphoric acid either being recycled or being further processed to produce ammonium phosphate fertilizer or technical grade phosphoric acid.

Atmospheric emissions from these processes include fluorides from the phosphate rock, particulates, sulphuric acid mist, sulphur dioxide, hydrogen chloride, methanol and potentially ammonia or other organic solvents. With the proper use of scrubbers on process streams within the plant and vent streams from the plant, these emission levels can be controlled effectively to meet applicable effluent guidelines. Fluoride emissions are controlled within the process in the Pennzoil case as potassium reacts with fluorides in the phosphate rock to produce insoluble potassium fluosilicate which is contained in the waste phosphogypsum.

Process water used in phosphoric acid production in the PCS/PECO case and in the potassium phosphate/phosphoric acid production unit in the Pennzoil case is higher in phosphate and fluoride content (PCS/PECO case), low in pH and, potentially, may have elevated radionuclide levels. Untreated release of process water to the surrounding environment would have a significant detrimental effect on the receiving waters. Treatment of the excess process water is normally accomplished with a double liming process in which the water is neutralized and solid precipitates are removed prior to discharge of the effluent. Recovered solids are combined with the phosphogypsum.

Waste phosphogypsum is traditionally stacked and ordinarily does not present unusual stability problems if placed on a suitable earthen foundation, clay or limestone. These storage piles are commonly considered to be unappealing in appearance and concerns have been expressed regarding their potential emission of fluorides or radon. Other possible phosphogypsum disposal methods include disposal in a large river or ocean or disposal in a landfill site. Disposal in a large river or ocean is considered to be environmentally unacceptable and therefore should not be explored. Disposal in a landfill site should only be considered if it is more economic than on site stacking.

Storage of process water in ponds, often practiced as a means of cooling the process water heated by the exothermic phosphate rock acidulation reaction, has the potential to contaminate groundwater sources by percolation or leaching through the pond-base soils. Similarly, process water or rainwater may percolate through the gypsum storage pile and base soil and contaminate surface or groundwater. By the proper selection of base soils or the use of clay or impervious liners, percolation of contaminated waters can be prevented.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on an overall assessment of the technologies under development for the manufacture of fertilizer grade potassium phosphates and the potential for market acceptance of a new fertilizer product, a number of technical and financial conclusions can be drawn.

1. A High Temperature Melt Process currently under development by The Potash Corporation of Saskatchewan (PCS) and Phosphate Engineering and Construction Co. (PECO) for the production of potassium phosphates from potash and wet process phosphoric acid appears to offer considerable potential. Both PCS and PECO are committed to its commercialization; accordingly, a continuous pilot plant is currently under construction with commissioning scheduled for the second quarter of 1988.

2. A Potassium Phosphate Process developed and partially demonstrated a number of years ago in semi-commercial facilities by Pennzoil for the production of potassium phosphates from potash, phosphate rock and sulphuric acid is also of interest although the final product separation stage has been demonstrated only in laboratory scale equipment. Pennzoil is no longer committed to the commercialization of the technology; however, PECO recently entered into an agreement with Pennzoil to develop prospects for this and related phosphate fertilizer technologies.

3. Potassium phosphate fertilizers offer distinct advantages over competitive potassium and phosphate fertilizers, potash and triple superphosphate or ammonium phosphates. Product advantages include a chloride-free material that can be used on chloride sensitive crops and in areas where chloride buildup in soils is of concern and good agronomic properties due to their slow release characteristics. In addition, shipping and storage costs would be lower than for the competitive fertilizers due to their high nutrient value, 80-85 percent for monopotassium phosphate and 90-100 percent for potassium polyphosphates.

4. The PCS/PECO High Temperature Melt Process appears to have a reasonable degree of financial potential, particularly if the potassium phosphate fertilizer product can command a premium price compared to the competitive products. The Pennzoil Process is less attractive in the Recycle Mode. The financial potential of both processes would be improved if the configuration and size of the fertilizer complex is changed so that other products, including ammonium phosphates or technical grade phosphoric acid, are produced in addition to the main potassium phosphate product.

5. An important parameter in the financial attractiveness of these technologies is the recovery and sale of by-product hydrochloric acid. Without this, the concept has little chance of success.

6. Construction and operation of a potassium phosphate fertilizer complex in the Cape Breton area of Nova Scotia would have a number of direct and indirect benefits on the region, including job opportunities and the resultant income, reduced unemployment and increased federal and provincial taxes. An estimated 160 full time direct and indirect jobs would be created for operation of the plant as well as additional opportunities during the construction phase of the project.

7. Atmospheric emissions from a potassium phosphate fertilizer complex would be similar to those experienced from a conventional wet process phosphoric acid plant. These emissions are well understood and the technology exists for their control to meet applicable effluent guidelines.

It is therefore recommended that a detailed feasibility study be undertaken on the basis of the PCS/PECO High Temperature Melt Process to more accurately evaluate the technical and financial viability of the potassium phosphate fertilizer technology and to better assess the market opportunity and probable price for potassium phosphate fertilizers.

The PCS/PECO Process was selected for a more detailed evaluation as it appears to offer both technical and financial potential and as PCS and PECO are both committed to its continued development and commercialization. Additionally, PCS has indicated a willingness to cooperate in a more detailed evaluation of the PCS/PECO potassium phosphate technology for potential application in Atlantic Canada.

Following are suggested terms of reference for the recommended detailed feasibility study, covering technical, marketing, financial, socio economic and environmental impact aspects of a potential potassium phosphate project:

Technical

- Assessment of the size of plant required to meet the market opportunity.

- Preparation of preliminary process design package for a given size potassium phosphate fertilizer plant, including Process Flowsheets, material and energy balances and sizing of all process equipment.

- Development of raw material and utility requirements for the potential plant.

- Assessment of the source of sulphur for sulphuric acid for use in the plant, either by-product sulphuric from Eastern or Atlantic Canada Smelters or elemental sulphur from Atlantic Canada petroleum refineries or from offshore.

- Specification of a sulphuric acid plant and integration of its operation with the potassium phosphate plant if elemental sulphur is identified as the preferred source of sulphur for the plant.

- Investigation of possible flexibility to be built into the fertilizer complex including the production of potassium polyphosphates as well as monopotassium phosphate and the production of ammonium phosphates, technical grade phosphoric acid or other phosphate fertilizers or feed grade products from additional wet process phosphoric acid.

- Assessment of the possible direct purchase of wet process phosphoric acid from an Atlantic Canada producer or from offshore for use as raw material to the potassium phosphate plant.

Basis for the technical evaluation should be information to be developed by PCS and PECO as a result of the operation of their continuous pilot plant which is currently under construction in Saskatchewan. Data from the proposed pilot plant program will confirm high temperature reactor operation in continuous equipment, evaluate the possible buildup of contaminants in recycle streams, establish overall raw material and energy efficiencies and provide information for the design of commercial scale facilities.

Marketing

- Assessment of the agronomic value of potassium phosphate fertilizers compared to the competitive potassium and phosphate fertilizers, in particular its chloride-free nature (low salt index) and its high nutrient value.

- Discussion of current and projected requirements for N, P and K fertilizers on a world wide basis.

- Analysis of the probable competitive position of potassium phosphate fertilizer in a market dominated by triple superphosphate is a source of P, ammonium phosphates as a source of N and P and potash as a source of K.

- Projection of the probable return on sales (price per tonne FOB Port) based on long term demand for P and K fertilizers, long term price projections for conventional fertilizers and an assessment of the premium that potassium phosphate fertilizers might command as a result of their chloride-free advantages over potash, the normal source of K.

- Discussion of probable markets and price for by-product hydrochloric and in steel pickling, oil and gas well acidulation (assuming commercialization of the Canadian East Coast oil and gas reserves) or chemical applications. Considerations will be given to anhydrous HCl as well as aqueous hydrochloric acid.

Financial

- Preparation of capital cost, operating cost and product revenue estimates for a potential potassium phosphate production facility of a given capacity, probably in the order of 100 000 tonnes per year of product.

- Preparation of a preliminary financial and sensitivity analysis to assess the financial potential of the proposed project. The sensitivity analysis should assess the effect of varying selected financial and cost parameters on the indicated project rate of return on investment. Key parameters to investigate in the sensitivity analysis are the capital cost, the cost of raw materials (potash, phosphate rock and sulphuric acid), product prices (potassium phosphate fertilizer and hydrochloric acid) and the impact of potential Federal or Provincial incentive programs on the project attractiveness.

Socio Economic

- Assessment of the direct and indirect socio economic benefits and impacts of the construction and operation of such a plant on the local community and region in general. Factors to be considered

would include employment opportunities, increased income in the area, increased federal and provincial taxes, ability of the existing infrastructure to support the project and the general benefits to industry in Atlantic Canada.

Environmental Impact

- Preparation of a detailed environmental impact assessment for such a project to identify potential atmospheric emissions and the technologies needed for their control in order to meet all Federal, Provincial and local environmental guidelines. Potential atmospheric omissions from a potassium phosphate fertilizer complex could consist of fluorides, particulates, sulphuric acid, sulphur dioxide, hydrogen chloride and possibly ammonia or organic solvents if other fertilizer or phosphate products are considered. Environmentally safe and aesthetic handling of waste phosphogypsum is also a concern that must be addressed.